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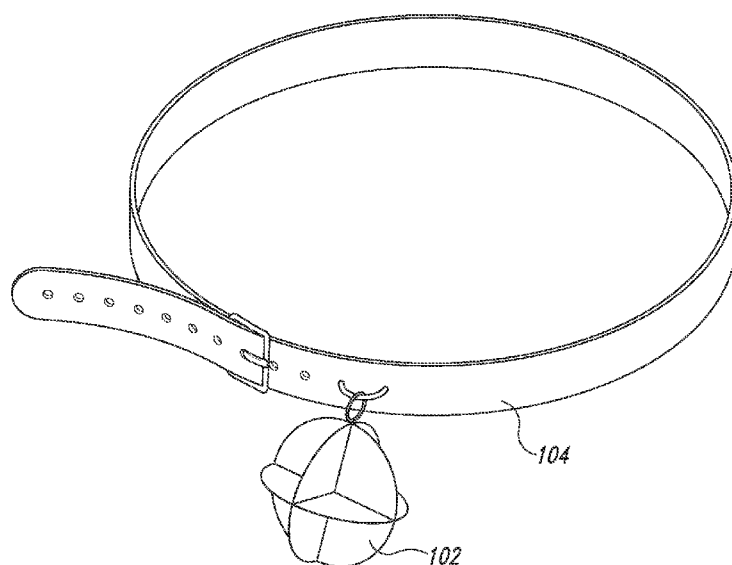
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(54) Title: SYSTEMS FOR PREVENTING COLLISIONS OF VEHICLES WITH PEDESTRIANS

FIG. 1



(57) Abstract: A wearable radar reflector includes a retroreflector configured to reflect radiation received from a vehicle, and incorporated into a garment worn by a pedestrian. A pedestrian warning system monitors an attention level of a pedestrian and alerts the pedestrian of traffic areas or detected vehicles.





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Systems for Preventing Collisions of Vehicles with Pedestrians

All subject matter of the Priority Applications and the Related Applications and of any and all parent, grandparent, great-grandparent, etc. applications of the Priority Applications and the Related Applications, including any priority claims, is incorporated herein by reference to the extent such subject matter is not inconsistent herewith.

SUMMARY

In one aspect, a wearable radar retroreflector includes a retroreflector (*e.g.*, a corner cube, a composite corner cube, or a Van Atta array) configured to reflect radiation having a frequency of about 1 to about 300 GHz (*e.g.*, about 70-85 GHz), and a garment configured to be worn by a pedestrian, wherein the retroreflector is attached to the garment and configured to retroreflect an information signal from a vehicle. The retroreflector may be configured to passively reflect the information signal or to boost its power. The retroreflector may receive the information signal and emit a response signal, which may include identifying information for the pedestrian (*e.g.*, position or demographics). The response signal may be encoded, for example, by a spatial dependence of the retroreflection or by vibration of the retroreflector, and may be emitted in response to a characteristic of the information signal (*e.g.*, signal strength, signal frequency, or signal content). The retroreflector may be powered, and may be configured to use power only under a predetermined condition (*e.g.*, time of day, date, location, or user status). The wearable radar retroreflector may include an accelerometer, which may be configured to record or report movement data of the retroreflector in response to receiving an information signal. The retroreflector may be configured to control the angular divergence of the retroreflected signal, and may have a frequency-dependent response. The wearable radar retroreflector may include a second retroreflector attached to the garment.

In another aspect, a method of preventing collisions includes receiving a radar signal having a frequency of about 1 to about 300 GHz (*e.g.*, about 70-85 GHz) at a

pedestrian location from a radar source, and retroreflecting the radar signal toward the radar source (*e.g.*, with a corner cube, a composite corner cube, or a Van Atta array), the retroreflection indicating information about the position of a pedestrian at the pedestrian location. The method may include reflecting the radar signal with a passive retroreflector or boosting the power of the reflected signal. The method may include transmitting a response signal, which may be encoded (*e.g.*, by a spatial dependence of the retroreflection or by vibrating the retroreflector). The response signal may include identifying or demographic information about the pedestrian. Retroreflecting the radar signal may include retroreflecting the radar signal in response to a characteristic of the radar signal (*e.g.*, signal strength, signal frequency, or signal content). The method may further include storing or reporting movement data for the pedestrian (*e.g.*, in response to receiving the radar signal). Retroreflecting the radar signal may include controlling the angular divergence of the retroreflected radar signal.

In another aspect, a method of preventing collisions includes sending a radar signal having a frequency of about 1 to about 300 GHz (*e.g.*, about 70-85 GHz) from an operating vehicle, receiving a retroreflected response radar signal (*e.g.*, with a corner cube, a composite corner cube, or a Van Atta array) from a pedestrian in response to the sent signal, and taking action to prevent the operating vehicle from striking the pedestrian or to mitigate the effect of striking the pedestrian (*e.g.*, by braking, changing direction, deploying a collision mitigation device such as an extendable bumper, an internal airbag, or an external airbag, or interpreting data from the retroreflected response radar signal to select an action). Receiving the retroreflected response radar signal may include receiving a passively retroreflected signal or a boosted radar signal. The method may include receiving a second retroreflected response radar signal from a second pedestrian or from a detected vehicle, in which case taking action may include avoiding both or prioritizing which to strike.

In a further aspect, a wearable radar retroreflector includes a retroreflector (*e.g.*, a corner cube, a composite corner cube, or a Van Atta array) configured to reflect radiation having a frequency of about 1 to about 300 GHz (*e.g.*, about 70-85 GHz), and a garment configured to be worn by a pedestrian, wherein the retroreflector is attached to the garment and configured to retroreflect an information signal from a vehicle. The

retroreflector may be configured to passively reflect the information signal or to boost its power. The retroreflector may receive the information signal and emit a response signal, which may include identifying information for the pedestrian (*e.g.*, position or demographics). The response signal may be encoded, for example, by a spatial dependence of the retroreflection or by vibration of the retroreflector, and may be emitted in response to a characteristic of the information signal (*e.g.*, signal strength, signal frequency, or signal content). The retroreflector may be powered, and may be configured to use power only under a predetermined condition (*e.g.*, time of day, date, location, or user status). The wearable radar retroreflector may include an accelerometer, which may be configured to record or report movement data of the retroreflector in response to receiving an information signal. The retroreflector may be configured to control the angular divergence of the retroreflected signal, and may have a frequency-dependent response. The wearable radar retroreflector may include a second retroreflector attached to the garment.

In another aspect, a method of preventing collisions includes receiving a radar signal having a frequency of about 1 to about 300 GHz (*e.g.*, about 70-85 GHz) at a pedestrian location from a radar source, and retroreflecting the radar signal toward the radar source (*e.g.*, with a corner cube, a composite corner cube, or a Van Atta array), the retroreflection indicating information about the position of a pedestrian at the pedestrian location. The method may include reflecting the radar signal with a passive retroreflector or boosting the power of the reflected signal. The method may include transmitting a response signal, which may be encoded (*e.g.*, by a spatial dependence of the retroreflection or by vibrating the retroreflector). The response signal may include identifying or demographic information about the pedestrian. Retroreflecting the radar signal may include retroreflecting the radar signal in response to a characteristic of the radar signal (*e.g.*, signal strength, signal frequency, or signal content). The method may further include storing or reporting movement data for the pedestrian (*e.g.*, in response to receiving the radar signal). Retroreflecting the radar signal may include controlling the angular divergence of the retroreflected radar signal.

In another aspect, a method of preventing collisions includes sending a radar signal having a frequency of about 1 to about 300 GHz (*e.g.*, about 70-85 GHz) from an

operating vehicle, receiving a retroreflected response radar signal (*e.g.*, with a corner cube, a composite corner cube, or a Van Atta array) from a pedestrian in response to the sent signal, and taking action to prevent the operating vehicle from striking the pedestrian or to mitigate the effect of striking the pedestrian (*e.g.*, by braking, changing direction, deploying a collision mitigation device such as an extendable bumper, an internal airbag, or an external airbag, or interpreting data from the retroreflected response radar signal to select an action). Receiving the retroreflected response radar signal may include receiving a passively retroreflected signal or a boosted radar signal. The method may include receiving a second retroreflected response radar signal from a second pedestrian or from a detected vehicle, in which case taking action may include avoiding both or prioritizing which to strike.

In another aspect, a radar identification device includes a memory configured to store demographic information for a user, and a radar retroreflector (*e.g.*, a Van Atta retroreflector) configured to be worn or carried by the user and further configured to modulate a retroreflected signal in the frequency range of about 1 to about 300 GHz (*e.g.*, about 50 to about 100 GHz, or about 70 to about 85 GHz) with at least a subset of the stored demographic information. The memory may be configured to update the stored demographic information, and may be configured to be worn or carried by the user. The radar retroreflector may be configured to select what demographic information to include in the modulated retroreflected radar signal. It may be a first radar retroreflector, and the device may include a second radar retroreflector, which may produce the same or a different retroreflected radar signal. The radar retroreflector may be configured to modulate the retroreflected signal ultrasonically. The demographic information may include species (*e.g.*, a dog, a cat, or another pet), age (*e.g.*, a child or an elderly person), sex, or physical capabilities (*e.g.*, maximum walking speed). The demographic information may include its leash status (*e.g.*, leashed, unleashed, on a retractable leash, or a leash length).

In another aspect, a wearable radar identification system includes an identification structure having a defined radar identification signature for radar in the frequency range of about 1 to about 300 GHz (*e.g.*, about 50 to about 100 GHz, or about 70 to about 85 GHz), the signature being associated with demographic information for an associated

user, and a garment incorporating the identification structure, configured to be worn by the associated user. For example, the identification structure may include an array of retroreflectors (which may have positions that encode the demographic information), or the identification structure may include a modulated retroreflector (*e.g.*, one configured to modulate the retroreflected signal ultrasonically, or a modulated Van Atta array), or the identification structure may include a radar beacon (*e.g.*, a radar-triggered radar beacon), or the identification structure may include a radar reflector. The demographic information may include species (*e.g.*, a dog, a cat, or another pet), age (*e.g.*, a child or an elderly person), sex, or physical capabilities (*e.g.*, maximum walking speed). The demographic information may include its leash status (*e.g.*, leashed, unleashed, on a retractable leash, or a leash length).

In another aspect, a method of preventing collisions includes receiving a radar signal having a frequency of about 1 to about 300 GHz (*e.g.*, about 50 to about 100 GHz, or about 70 to about 85 GHz) at a pedestrian location from a radar source, and transmitting a response signal toward the radar source (*e.g.*, in response to receiving the radar signal), where the response signal includes demographic information about the pedestrian, and is automatically sent without action by the pedestrian. Transmitting the response signal may include retroreflecting the radar signal back toward the radar source with encoded demographic information about the pedestrian (*e.g.*, with a modulated retroreflected signal, or by encoding the information via the positions of the array of retroreflectors), using a radar beacon, or reflecting the radar signal with a radar reflector. The demographic information may include species (*e.g.*, a dog, a cat, or another pet), age (*e.g.*, a child or an elderly person), sex, or physical capabilities (*e.g.*, maximum walking speed). The demographic information may include its leash status (*e.g.*, leashed, unleashed, on a retractable leash, or a leash length), or companions (*e.g.*, whether a child is accompanied by an adult). The response signal may be transmitted only if the pedestrian is near a roadway (*e.g.*, within a predetermined distance such as a user-determined distance) or otherwise in response to a position of the pedestrian.

In another aspect, a method of preventing collisions includes sending a radar signal from an operating vehicle, receiving a response signal (*e.g.*, a retroreflected response signal) including demographic information about a pedestrian in response, and

taking action to prevent the operating vehicle from striking the pedestrian or to mitigate the effect of striking the pedestrian. Taking action may include taking action in response to the demographic information. The demographic information may include species (*e.g.*, a dog, a cat, or another pet), age (*e.g.*, a child or an elderly person), sex, or physical capabilities (*e.g.*, maximum walking speed). The demographic information may include its leash status (*e.g.*, leashed, unleashed, on a retractable leash, or a leash length).

In a further aspect, a pedestrian warning device includes a radar detector configured to be worn or carried by a pedestrian and to detect radar signals coming from a vehicle, and an alarm configured to warn the pedestrian of the vehicle. The alarm may be audible (*e.g.*, a prerecorded or synthesized voice), visual, or haptic. The alarm may indicate a location or other information about the vehicle (*e.g.*, direction, proximity, range, time-to-impact, color, make, or model), and may include a command for the pedestrian (*e.g.*, freeze, slow down, speed up, move in a particular direction, brake). The device may include a decision unit configured to determine whether to sound the alarm, which may be configured to decide whether to sound the alarm or to customize the alarm based at least in part on the pedestrian's position, the pedestrian's orientation, the pedestrian's movement direction, the pedestrian's speed, the pedestrian's companions, the pedestrian's movement history, the vehicle's range, the vehicle's direction, the vehicle's speed, the vehicle's time to impact, or the position of a second vehicle. The device may include transmission means configured to communicate to the vehicle, which may include a radar transmitter, a lidar transmitter, a reflector, a retroreflector (*e.g.*, a modulated retroreflector), and may be configured to communicate detection of vehicle, issued alert, the pedestrian's position, the pedestrian's speed, or pedestrian's response to alert. The device may include a recording unit that may be configured to record the signal emanating from the vehicle, the time of the signal, the location of the vehicle, the location of the pedestrian, the speed of the vehicle, the direction of the vehicle, the time-to-impact, the speed of the pedestrian, the position of the pedestrian, any alarms issued, or any reaction of the pedestrian to an issued alarm. The device may include control means configured to issue a control directive (*e.g.*, a command to brake, a command to stop, a command to change direction, a command to change speed, and a command to activate a driver alert) to a pedestrian vehicle under control of the pedestrian (*e.g.*, a

bicycle, an electric-assisted bicycle, a skateboard, a motorized skateboard, a scooter, a motorized skateboard, a motorized scooter, a personal transporter, a wheelchair, or a powered wheelchair). The device may be a cellular telephone. The device may be configured to determine a characteristic of the detected radar signal (*e.g.*, direction, frequency, Doppler shifts, amplitude, waveform, or informational modulation of the radar signal). The device may include an accelerometer (in which case it may have a control system configured to use data from the accelerometer to determine a response of the pedestrian to a warning), a GPS receiver, or a digital memory configured to store digital mapping data.

In another aspect, a pedestrian warning device includes a lidar detector configured to be worn or carried by a pedestrian and to detect lidar signals coming from a vehicle, and an alarm configured to warn the pedestrian of the vehicle. The alarm may be audible (*e.g.*, a prerecorded or synthesized voice), visual, or haptic. The alarm may include a command for the pedestrian (*e.g.*, freeze, slow down, speed up, move in a particular direction, brake). The device may include a decision unit configured to determine whether to sound the alarm, which may be configured to decide whether to sound the alarm or to customize the alarm based at least in part on the pedestrian's position, the pedestrian's orientation, the pedestrian's movement direction, the pedestrian's speed, the pedestrian's companions, the pedestrian's movement history, the vehicle's range, the vehicle's direction, the vehicle's speed, the vehicle's time to impact, or the position of a second vehicle. The device may include transmission means configured to communicate to the vehicle. The device may include a recording unit that may be configured to record the signal emanating from the vehicle, the time of the signal, the location of the vehicle, the location of the pedestrian, the speed of the vehicle, the direction of the vehicle, the time-to-impact, the speed of the pedestrian, the position of the pedestrian, any alarms issued, or any reaction of the pedestrian to an issued alarm. The device may include control means configured to issue a control directive to a pedestrian vehicle under control of the pedestrian. The device may include an accelerometer (in which case it may have a control system configured to use data from the accelerometer to determine a response of the pedestrian to a warning), a GPS receiver, or a digital memory configured to store digital mapping data.

In another aspect, a method of warning a pedestrian of a vehicle includes receiving a radar signal from the vehicle at a radar detector configured to be worn or carried by the pedestrian, and alerting the pedestrian with an alarm. Alerting the pedestrian may include alerting the pedestrian with a sound (*e.g.*, a prerecorded or synthesized voice), visually, or haptically. Alerting the pedestrian may include issuing a command to the pedestrian (*e.g.*, freeze, slow down, speed up, move in a particular direction, brake), or giving the pedestrian information about the vehicle (*e.g.*, direction, proximity, range, time-to-impact, color, make, or model). Alerting the pedestrian may include alerting the pedestrian (*e.g.*, by issuing an alarm) in response to of the pedestrian's position, the pedestrian's orientation, the pedestrian's movement direction, the pedestrian's speed, the pedestrian's companions, the pedestrian's movement history, the vehicle's range, the vehicle's direction, the vehicle's speed, the vehicle's time to impact, or the position of a second vehicle. The method may further include transmitting a response signal back to the vehicle (*e.g.*, a radar signal, a lidar signal, a reflected radar signal, a retroreflected radar signal, or a modulated retroreflected radar signal), which may include reporting of detection of the vehicle, issued alert, the pedestrian's position, the pedestrian's speed, or pedestrian's response to alert. The method may further include recording the signal emanating from the vehicle, the time of the signal, the location of the vehicle, the location of the pedestrian, the speed of the vehicle, the direction of the vehicle, the time-to-impact, the speed of the pedestrian, the position of the pedestrian, any alerts issued, or any reaction of the pedestrian to an issued alert, or it may include transmitting a control directive (*e.g.*, a command to brake, a command to stop, a command to change direction, a command to change speed, and a command to activate a driver alert) to a pedestrian vehicle under control of the pedestrian (*e.g.*, a bicycle, an electric-assisted bicycle, a skateboard, a motorized skateboard, a scooter, a motorized skateboard, a motorized scooter, a personal transporter, a wheelchair, or a powered wheelchair). The method may further include determining a characteristic of the detected radar signal (*e.g.*, direction, frequency, Doppler shifts, amplitude, waveform, or informational modulation), and may include using an accelerometer to determine a response of the pedestrian to the alarm.

In another aspect, a method of warning a pedestrian of a vehicle includes receiving a lidar signal from the vehicle at a lidar detector configured to be worn or carried by the pedestrian, and alerting the pedestrian with an alarm. Alerting the pedestrian may include alerting the pedestrian with a sound (*e.g.*, a prerecorded or synthesized voice), visually, or haptically. Alerting the pedestrian may include issuing a command to the pedestrian (*e.g.*, freeze, slow down, speed up, move in a particular direction, brake), or giving the pedestrian information about the vehicle (*e.g.*, direction, proximity, range, time-to-impact, color, make, or model). Alerting the pedestrian may include alerting the pedestrian (*e.g.*, by issuing an alarm) in response to of the pedestrian's position, the pedestrian's orientation, the pedestrian's movement direction, the pedestrian's speed, the pedestrian's companions, the pedestrian's movement history, the vehicle's range, the vehicle's direction, the vehicle's speed, the vehicle's time to impact, or the position of a second vehicle. The method may further include recording the signal emanating from the vehicle, the time of the signal, the location of the vehicle, the location of the pedestrian, the speed of the vehicle, the direction of the vehicle, the time-to-impact, the speed of the pedestrian, the position of the pedestrian, any alerts issued, or any reaction of the pedestrian to an issued alert, or it may include transmitting a control directive to a pedestrian vehicle under control of the pedestrian. The method may further include using an accelerometer to determine a response of the pedestrian to the alarm.

In another aspect, a pedestrian warning device includes a vehicle detector configured to be worn or carried by a pedestrian and to detect signals emanating from a vehicle, and an alarm configured to warn the pedestrian of the vehicle. The vehicle detector may include a wide-angle camera. The device may include a transmitter configured to transmit information about the pedestrian to the vehicle. The transmitter may be passive (*e.g.*, a retroreflector) or powered (*e.g.*, by a battery or by the pedestrian).

In another aspect, a pedestrian warning system includes a beacon radar transmitter configured to transmit a radar signal including vehicle information (*e.g.*, speed, direction, position, maximum speed, braking capabilities, turning capabilities, make, model, color, or driver identifying information), wherein the transmitted signal may be received by a pedestrian to communicate vehicle information to the pedestrian.

In a further aspect, a pedestrian warning device includes a computing device (*e.g.*, a mobile telephone or wearable device) configured to be worn or carried by a pedestrian and to monitor an attention level of the pedestrian, and an alarm (*e.g.*, an audible, visible, or haptic alarm) configured to warn the pedestrian of a vehicle detected by the computing device. The pedestrian device may include a camera or a microphone configured to detect the vehicle. The alarm may be configured to warn the pedestrian only if a predicted collision probability is above a threshold, or the attention level of the pedestrian is below a threshold. The alarm may be in response to the attention level of the pedestrian, or in a mode selected in response to the attention level of the pedestrian. The alarm may be in a mode selected in response to an activity type of the pedestrian (*e.g.*, typing, talking, taking a picture, taking a video, having a video conference, playing a timed game, playing an untimed game, reading, watching a display, or using a display-based application). The alarm may be configured to warn the pedestrian in response to attention history, eye position, eye position history, head orientation, head orientation history, position or motion of the pedestrian, position or motion of the computing device, or alarm response history of the pedestrian. The pedestrian warning device may further include a GPS configured to identify a location of the pedestrian (*e.g.*, to determine if the pedestrian is crossing a street at an intersection), and may monitor the gaze or head position of the pedestrian and warn the pedestrian if he attempts to cross without looking in a direction of oncoming traffic. The pedestrian warning device may further include a sensor configured to monitor a traffic signal, in which case the alarm may be configured to alert the pedestrian if he attempts to cross the street in contravention of the traffic signal. The pedestrian warning device may further include a memory, which may be configured to store a record of the pedestrian's actions, a record of vehicle detections, or a record of alarms issued.

In another aspect, a method of warning a pedestrian of a vehicle includes monitoring an attention level of the pedestrian by monitoring an electronic device carried or worn by the pedestrian (*e.g.*, a mobile telephone or wearable device), detecting a vehicle (*e.g.*, with a camera or microphone), and, in response to the detected vehicle and the monitored attention level, alerting the pedestrian to the presence of the vehicle (*e.g.*, with a visual, audible, or haptic alarm). Alerting the pedestrian may include alerting the

pedestrian in response to an attention level, attention history, eye position, eye position history, head orientation, head orientation history, alarm response history, position, or motion of the pedestrian, or in response to a position or motion of the device. Monitoring the attention level may include monitoring a device activity (*e.g.*, typing, talking, taking a picture, taking a video, having a video conference, playing a timed game, playing an untimed game, reading, watching a display, or using a display-based application), in which case an alert mode may be selected in response to the device activity. The method may further include storing data in a memory, such as a record of the pedestrian's actions, a record of vehicle detections, or a record of pedestrian alerts.

In another aspect, a system for monitoring the behavior of a pedestrian includes a computing device configured to be worn or carried by a pedestrian, to monitor an attention level of the pedestrian, and to detect a vehicle (*e.g.*, with a camera or microphone), and a memory configured to store information about the actions of the pedestrian. The system may further include a transmitter configured to transmit information about the actions of the pedestrian to a remote location, or a display configured to display information stored in the memory. The device may be configured to store a record of pedestrian activity (*e.g.*, typing, talking, taking a picture, taking a video, having a video conference, playing a timed game, playing an untimed game, reading, watching a display, or using a display-based application). The system may further include a GPS configured to identify a location of the pedestrian, in which case the memory may be configured to store the identified location. The memory may be configured to store gaze direction, head position, device orientation, or a record of vehicle detections.

In another aspect, a method for monitoring the behavior of a pedestrian includes monitoring an attention level, a position, and a motion of the pedestrian, and alerting the pedestrian (*e.g.*, with a visible, audible, or haptic alarm) if the pedestrian is determined to be in danger from a vehicle in response to the monitored data. Monitoring the position of the pedestrian may include determining the proximity of the pedestrian to a street (*e.g.*, with a GPS, a camera, or a microphone). A GPS may monitor the position or motion of the pedestrian. Monitoring motion may include determining that the pedestrian is moving toward a street. Alerting the pedestrian may be in response to an attention level,

attention history, eye position, eye position history, head orientation, head orientation history, device orientation, device orientation history, or alarm response history. Monitoring the attention level may include monitoring a device activity of the pedestrian (e.g., typing, talking, taking a picture, taking a video, having a video conference, playing a timed game, playing an untimed game, reading, watching a display, or using a display-based application), in which case it may further include selecting an alert mode in response to the device activity. The method may further include storing a record of vehicle detections or pedestrian alerts in a memory.

The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a schematic of a retroreflector for use on a pet.

FIG. 2 is a schematic of a retroreflector for use on a child.

FIG. 3 is a schematic of an amplified Van Atta array.

FIG. 4 is a schematic of an array of retroreflectors.

FIG. 5 is a schematic of a powered Van Atta array for attachment to a pedestrian.

FIG. 6 is a flow chart showing operation of a retroreflector for collision avoidance.

FIG. 7 is a flow chart showing the method of preventing collisions from the vehicle side.

FIG. 8 is a schematic of a radar-triggered radar beacon.

FIG. 9 shows a cellular telephone running an application for warning a pedestrian.

FIG. 10 shows a wearable device running an application that detects a vehicle and warns a pedestrian.

FIG. 11 is a flowchart illustrating the use of the applications shown in **FIG. 9** and **FIG. 10**.

FIG. 12 is a flowchart illustrating another use of the applications shown in **FIG. 9** and **FIG. 10**.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here.

“Retroreflector,” as that term is used herein, includes “passive” retroreflectors that reflect a signal back in the direction from which it came (*e.g.*, a corner cube or a Van Atta array), and also “active” retroreflectors which boost or filter a received signal or send a modulated response signal back in the direction from which a signal was received (*e.g.*, a Van Atta array including switches for modulation of the retroreflection, as described in Thornton, *et al.*, “Modulating retro-reflector as a passive radar transponder,” *Elect. Lett.* (Sept. 1998) **34**(19):1880-1881).

“Garment,” as that term is used herein, includes clothing, apparel, or jewelry such as but not limited to shirts, coats, pants, shoes, hats, collars, bracelets, earrings, belts, or backpacks, and also objects designed to be carried by pedestrians, such as but not limited to briefcases, purses, suitcases, keyfobs, cellphones, or tablets.

“Pedestrian,” as that term is used herein, includes a person or pet that is not currently in a vehicle, or is using a “pedestrian vehicle” typically permitted on a sidewalk, such as a bicycle, wagon, skateboard, scooter, wheelchair (including motorized wheelchairs), or personal transport such as a SEGWAY™. Pedestrians may include adults, children, dogs, cats, livestock, or other animals, unless context dictates that the pedestrian must be human. (For example, a texting pedestrian is presumed to be human.) “Demographics” of a pedestrian may include age, sex, physical capabilities (or capabilities of a pedestrian vehicle in use), or other relevant information about the pedestrian. “Identifying information” of a pedestrian may include information such as name, address, guardian, next-of-kin, owner, or the like.

Cars and trucks are increasingly being outfitted with technological systems for collision avoidance. In particular, cars and trucks are beginning to include radar systems, primarily for detecting other vehicles for collision avoidance or for convoying. Radar retroreflectors may be detected by such systems and therefore may be used to “mark” the locations of pedestrians to avoid collisions (for example, children or pets, who may be less aware of vehicles in their vicinity than adults).

FIG. 1 shows a simple corner cube configured for attachment to a pet. The corner cube **102** is attached to a collar **104**, which may be any conventional collar and may include standard safety features such as a breakaway attachment to prevent strangulation if the collar catches on a branch or the like. Current vehicle radar systems typically use frequencies of around 75-80 GHz, corresponding to a full wavelength of about 4 mm; a corner cube having a longest dimension of a centimeter or two is adequately reflective for these frequencies. Conventional corner cubes feature three intersecting orthogonal planes, and hence one octant of angular space, i.e., 90° in longitude and latitude. Accordingly, in order to properly retroreflect a radar beam, they must be oriented toward the incident beam such that it arrives within their acceptance angle. For some embodiments, the orientation of the pedestrian’s garment towards a vehicular radar beam may not be such that a simple corner cube mounted on it will be adequately pointed towards the beam. To address this issue, composite corner cubes may be used, comprising multiple coattached corner cubes facing in different directions. For instance, a composite corner cube may feature 2 back-to-back cornercubes spanning 180 degrees in one direction, or 4 cornercubes filling a hemispherical solid angle. Composite corner cubes having eight back-to-back corner cubes, such as described by Xian Jin in “Integrated Optical Devices for Free-Space Optical Communications”, Master of Applied Science Thesis, University of British Columbia, 2009, can be used to provide retroreflection for all orientations or beam directions.

FIG. 2 shows a Van Atta array incorporated into a child’s shirt. It will be understood that the array may be smaller or larger than the illustrated embodiment, which is of a size selected to show an appropriate level of detail. The array **202** may be placed, for example, on a circuit board **204** or the like, with apertures **206** on the front of the board and connecting transmission lines **208** placed on the back of the board to form the

array. Transmission lines **208** may be implemented as striplines, microstrips, waveguides, coax, wires, or any other transmission line technology commensurate with the incident radar frequency. (Transmission lines **208** all have the same length to achieve retroreflection.) Transmission lines **208** may be designed for broadband frequency response, for example to accommodate a wide range of vehicular radar frequencies. Alternatively, transmission lines **208** may be designed to only operate over a limited band of frequencies, either due to the passive frequency response of the transmission line or attached external filters, or via situationally switching in or out external filters.

Board **204** is attached to the shirt so that it retroreflects whenever the child is in radar range of a vehicle. Outer clothing generally will allow RF radiation to pass with minimal scattering, so that the board has its retroreflective effect even if the child dons a coat or sweater over the array. The array may be configured to control the angular divergence of the retroreflected signal.

In some embodiments, the retroreflector **202** may modulate the retroreflection in order to send a response signal encoding additional additional information such as the identity, demographics, or position of the pedestrian, or to more clearly mark the reflection as coming from a pedestrian. In some embodiments, the modulation may be applied by vibrating the surface of the retroreflector (*e.g.*, corner cube, Van Atta Array), as disclosed for optical corner cubes in US Patent 5909279. In some embodiments, the modulation can be introduced electronically (*e.g.*, injected into the transmission lines of a Van Atta Array) as described in Thornton, *et al.* In some embodiments, the modulation may be selected in response to a characteristic of the incoming signal, for example its strength, frequency, or information content. As examples, the strength of an incident radar signal may indicate that the radar source is relatively close, the frequency of the radar signal may indicate that it is used for parking purposes rather than for collision avoidance purposes, or the incident radar signal may be encoded with a query as to the type of target it is hitting.

As mentioned above, in some embodiments, retroreflector **202** may be configured to modulate the retroreflection, thereby sending information back to the radar emitter. This information may include, for example, demographic or identifying information about the pedestrian. In some embodiments, it may further include information such as

the identity or demographics of other pedestrians, which may be used by the radar source to assess risk. For example, a child accompanied by a parent may be considered less likely to run into the street, while a child accompanied only by his peers may be even more likely to behave unpredictably than a child alone. Similarly, a leashed pet is unlikely to be permitted to dart in front of a car. Demographic information may include, for example, a characteristic or a maximum walking speed, which may be used to assess whether a pedestrian is capable of getting out of the way of the vehicle.

FIG. 3 shows a Van Atta array similar to the one illustrated in **FIG. 2**, but with amplifiers placed to boost the retroreflected signal. The array of **FIG. 3** includes four apertures **302**, with each pair connected by two amplifiers **304** and two circulators **306**, in the arrangement shown by Bird, *RTO-MP-SCI-145* (Apr. 2004). It will be understood that amplifiers **304** and/or circulators **306** are powered to increase the retroreflection. In another embodiment, a steerable antenna such as those described in U.S. Patent Application Publication No. 2012/0194399 can be used as a retroreflector. Such an antenna may reflect a signal, or may absorb it and reemit a signal in the direction from which it was received. The reflected or reemitted signal may be selected in response to a characteristic of the incoming signal, for example its strength, frequency, or information content.

FIG. 4 shows an array of retroreflectors **402**. The illustrated array is of Van Atta reflectors like that shown in **FIG. 2**, but corner cubes, steerable antennas, or other retroreflectors may also be used. The placement of retroreflectors within the array may create a characteristic spatial pattern at the radar receiver that identifies the wearer generally as a pedestrian, or with more specific demographic information (*e.g.*, that the wearer is a child, an elderly person, a dog, or a cat).

FIG. 5 shows a Van Atta Array **502** connected to a power source **504**. The assembly may be connected to a collar of a pet, as a zipper pull on a child, or placed in a purse, briefcase, backpack, or pocket. Array **502** may retroreflect even without being powered, but sends a stronger signal when power is used. To preserve battery life, array **502** is configured to draw power only under certain conditions. Alternatively, the retroreflection can be situationally controlled (even for non-power-boosted arrays) by incorporating switches in the inter-element transmission lines of Van Atta array **502**, as

described in Thornton, *et al.* For example, an array 502 may engage when a pet is released from a leash, when a wearer is in proximity to a street, during specified times of day (*e.g.*, after school on school days, and all day on weekends), or combinations of such conditions (*e.g.*, outside of school hours when the user is near a street). Situational control can enhance the pedestrian's privacy (so he is only tracked when at risk from traffic) as well as to limit the number of retroreflecting signals a vehicle's radar must handle to those which are traffic-relevant. In some embodiments, array 502 may be connected to an accelerometer 506 to record movement of the pedestrian. For example, accelerometer 506 may continuously monitor acceleration, and save the last few minutes of data after a rapid acceleration of the pedestrian indicates an impact, or when a signal is received indicating that a radar source is nearby. Recorded movement data can be reported to authorities or to insurance personnel (*e.g.*, after a collision), or to the radar source (*e.g.*, by encoding the retroreflection).

FIG. 6 is a flow chart showing how any of the previously described retroreflectors may be used. The method includes receiving 602 a radar signal having a frequency in the range of about 1 to about 300 GHz (*e.g.*, about 70 to about 85 GHz) at a pedestrian location, and retroreflecting 604 the radar signal toward the radar source, where the retroreflection provides information to the radar source about a position of the pedestrian. The retroreflection may also provide other information as described above, such as the demographics of the pedestrian, which may be used by a vehicular radar source as described below.

FIG. 7 is a flow chart showing how a vehicle may use the retroreflected signals described above to prevent or mitigate collisions. The method includes sending 702 a radar signal from an operating vehicle (*e.g.*, a signal in the range of about 1 to about 300 GHz, or in the range of about 75 to about 80 GHz), receiving 704 a retroreflected signal from the pedestrian in response, and taking action 706 to prevent the vehicle from striking the pedestrian or to mitigate the effects of striking the pedestrian (*e.g.*, if the signal is received too late to avoid a collision entirely). Actions 706 that may be taken include but are not limited to braking the vehicle or changing direction of the vehicle. In some embodiments, the vehicle may include logic circuits configured to interpret data from the retroreflection (*e.g.*, demographic information or movement history) in order to

choose a course of action. These logic circuits may be configured to further interpret signals received from a second location (*e.g.*, retroreflected signals from a second pedestrian). Such circuits may be configured to prioritize which source should be struck, if a collision cannot be prevented entirely (*e.g.*, to hit a dog instead of a child). The circuits may be customizable by a user. For example, those most concerned with loss of life may prefer to hit another vehicle (presumably equipped with seat belts and other safety equipment) instead of a dog, while those most concerned with monetary costs may prefer to hit the dog and avoid the other vehicle. In either case, of course, the effects of the collision may be mitigated by braking, steering to strike a glancing blow, deploying collision mitigation devices such as airbags or extendable bumpers, steering to hit a bumper instead of a more vulnerable part of the car, etc. Other user-customizable features may include whether to warn a driver or to simply override his control of a car, for example depending on how close the pedestrian is and how much time is available to avoid the collision.

FIG. 8 shows in exploded view a radar beacon **802** incorporated into a bracelet **804**. Illustrated beacon **802** is powered by power source **806**, which in some embodiments may be switchable as described above to be active only under certain conditions (*e.g.*, when the wearer is at risk due to traffic). The illustrated beacon **802** is covered by a decorative bezel **808** so that it appears simply to be a bracelet. In such embodiments, this type of design may increase user acceptance when the beacon is to be worn by a child.

Pedestrians must maintain awareness of their surroundings to avoid being struck by cars or other vehicles. This awareness is sometimes compromised by pedestrians' use of electronics. Mobile phones and texting can be particularly absorbing, as can various games available on "smart" phones and other devices. Furthermore, children, pets, and even adults caught by surprise may panic at the sight of an oncoming vehicle and may use counterproductive avoidance strategies like trying to outrun a car. A system that uses ingrained reflexes, especially when issued before the oncoming vehicle is seen (*e.g.*, in a parent's voice), may produce more productive behavior.

FIG. 9 illustrates an implementation of a pedestrian warning system designed to alert a pedestrian who is distracted by texting. Telephone **1302** includes a global

positioning system (GPS) **1304**, that monitors the location of the pedestrian relative to the street. (In some embodiments, the phone may also use its camera **1308** or its microphone **1310** to detect a vehicle, and may optionally modify its warnings in response to such detection.) In the embodiment shown in **FIG. 9**, while the phone was being used for texting, a warning box **1306** shows that the pedestrian is approaching an intersection. The illustrated phone **1302** also includes a traffic light sensor **1312**, and the display indicates the light is red (“NO CROSSING”). (Traffic light sensors are described, for example, in US Pat. No. 6,985,073.) While element **1312** is shown in **FIG. 9** as the traditional symbol for a photodiode, which may be configured to directly “look at” the traffic signal and respond to its color, it may also be implemented as an antenna or other device configured to receive a broadcast signal from the traffic signal, or a microphone or similar device configured to interpret an audible signal from the traffic signal. The words “NO CROSSING” may change to “GREEN LIGHT” or a pedestrian walking symbol or any other appropriate symbol or message when the pedestrian is permitted to cross. In this or other embodiments, telephone **1302** may also (or instead) emit an audible or haptic alarm. In some embodiments, the first alarm may be audible, for example, with warning box **1306** appearing over the texter’s screen only when it appears that he may be about to step into the intersection. In some embodiments, an audible alarm may be recorded in the voice of the pedestrian’s parent or guardian, or another authority figure that the pedestrian is expected to reflexively obey.

In another embodiment, **FIG. 10** shows an a wearable device **1402** that is configured to detect a vehicle **1404** and to warn the pedestrian of it. In the illustrated embodiment, the vehicle is detected via microphone **1406** of device **1402**, which monitors for a characteristic engine noise. In other embodiments, the device may use a camera to watch for cars or other vehicles. These embodiments are expected to perform better at detecting electric vehicles, which may be relatively silent compared to conventional internal-combustion engines. However, makers of electric vehicles sometimes include audio recordings of engine noise to prevent pedestrians from being taken by surprise. In some embodiments, the device may listen specifically for such recordings. Apps may include sound libraries or other methods of recognizing such

sounds, especially if, in the future, recorded or digitally-generated sounds become standard for such cars.

In the illustrated embodiment, microphone **1406** is a stereo microphone that allows device **1402** to identify the approximate direction of vehicle **1404**. In some embodiments, a monaural microphone may be used. Even though this does not typically permit the direction of the vehicle to be determined without additional hardware, device **1402** is still able to warn the pedestrian of the vehicle. In some embodiments, the device's camera may supplement (*e.g.*, looking for a car once it has been detected by the microphone) or replace the microphone for vehicle detection. The wearable device illustrated in **FIG. 10** may also monitor a head position (or eye direction) of the pedestrian as further described below.

In some embodiments, device **1402** (or phone **1302**) may include a memory configured to store information about the actions of the pedestrian. In such embodiments, the device may optionally also warn the pedestrian of approaching vehicles, but the memory may provide a record of the pedestrian's behavior in response to vehicles that may be reviewed by the pedestrian or his parent or guardian. This review may be used to facilitate behavior management systems to improve the safety of the pedestrian in the presence of traffic.

FIG. 11 is a flowchart **1500** showing how the pedestrian warning system of **FIG. 9** or **FIG. 10** may be used. The system continuously (or intermittently) monitors **1502** an attention level of a pedestrian, for example by monitoring the activity of the pedestrian on the device or by monitoring his head position or eye position (gaze direction) to determine whether he is looking for traffic. The system also detects **1504** a vehicle, for example using a camera, microphone, or both. In some embodiments, the system may proceed directly to alerting the pedestrian, while in others, it first determines **1508** whether to alert (or how to alert, as described below). For example, if the device has been monitoring head position, it may decide to alert only if the pedestrian has not turned his head in the direction of the vehicle recently. In response to the detected vehicle and the monitored attention level, the device alerts **1506** the pedestrian to the vehicle. The form of the alert may be determined by the attention level or device activity. For example, the device may use a visual alert **1510** when the pedestrian is looking at a

handheld device (*e.g.*, texting or watching a video), or an audio alert **1512** or haptic alert **1514** when the pedestrian is not looking at a handheld device (*e.g.*, talking on the phone or wearing the device shown in **FIG. 10**). Multiple alerts may be given sequentially or simultaneously depending on the response to the first alert. The details of the alarms used and the conditions under which the device will alert the user may be user-defined, either by the pedestrian or by another user (*e.g.*, a parent or guardian).

In some embodiments, step **1506** may be omitted from the method illustrated in **FIG. 11**, and the device may be used simply to create a record of pedestrian (and optionally vehicle) behavior, as shown in **FIG. 12**. The device monitors **1602** an attention level of the pedestrian and detects **1604** a vehicle as described above. Optionally, it may issue an alert as described in connection with **FIG. 11** (optional step not depicted in **FIG. 12**). It stores **1606** a record of the behavior of the pedestrian around the vehicle in a memory (*e.g.*, did the pedestrian look at the vehicle, did the pedestrian slow down or stop at an intersection, did the pedestrian pause in using the device as the vehicle approached). It may also store **1608** a record of the behavior of the vehicle (*e.g.*, did it stop, did it slow down, did it approach the pedestrian too closely). Such a record may be used, for example, to instruct the pedestrian about proper behavior in future encounters, or to provide a record in the event of a collision or near-miss between the vehicle and the pedestrian. In some embodiments, detection **1604** of the vehicle may be omitted and instead (or additionally) the device may use a GPS or other device to identify the position of the pedestrian and record his behavior in the vicinity of expected traffic positions such as streets.

Various embodiments of devices and methods have been described herein. In general, features that have been described in connection with one particular embodiment may be used in other embodiments, unless context dictates otherwise. For example, the corner cubes described in connection with **FIG. 1** may be employed in the devices described in connection with **FIG. 4**, or with any of the embodiments described herein. For the sake of brevity, descriptions of such features have not been repeated, but will be understood to be included in the different aspects and embodiments described herein.

All of the aforementioned U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent

publications referred to in this specification, or listed in any Application Data Sheet, are incorporated herein by reference, to the extent not inconsistent herewith. This incorporation by reference specifically includes any materials that are incorporated by reference into the aforementioned U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications.

While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

1. A wearable radar reflector, comprising:
a retroreflector configured to reflect radiation having a frequency of about 1 to about 300 GHz; and
a garment configured to be worn by a pedestrian, wherein the retroreflector is attached to the garment and configured to retroreflect an information signal from a vehicle.
2. The wearable radar reflector of claim 1, wherein the retroreflector is configured to passively reflect the information signal.
3. The wearable radar reflector of claim 1, wherein the retroreflector is configured to boost the power of the retroreflected information signal.
4. The wearable radar reflector of claim 1, wherein the retroreflector is configured to receive the information signal and to emit a response signal.
5. The wearable radar reflector of claim 4, wherein the response signal includes identifying information for the pedestrian.
6. The wearable radar reflector of claim 5, wherein the identifying information for the pedestrian includes the position of the pedestrian.
7. The wearable radar reflector of claim 5, wherein the identifying information for the pedestrian includes the demographics of the pedestrian.
8. The wearable radar reflector of claim 4, wherein the response signal is encoded by a spatial dependence of the retroreflection.
9. The wearable radar reflector of claim 4, wherein the response signal is frequency encoded by vibration of the retroreflector.
10. The wearable radar reflector of claim 4, wherein the response signal is emitted in response to a characteristic of the information signal.

11. The wearable radar reflector of claim 10, wherein the characteristic of the information signal is selected from the group consisting of signal strength, signal frequency, and signal content.
12. The wearable radar reflector of claim 1, wherein the retroreflector is powered.
13. The wearable radar reflector of claim 12, wherein the retroreflector is configured to use power only under a predetermined condition.
14. The wearable radar reflector of claim 13, wherein the predetermined condition is selected from the group consisting of time of day, date, location, and user status.
15. The wearable radar reflector of claim 1, further comprising an accelerometer.
16. The wearable radar reflector of claim 15, wherein the accelerometer is configured to record movement data of the retroreflector in response to receiving the information signal.
17. The wearable radar reflector of claim 15, wherein the accelerometer is configured to report movement data of the retroreflector in response to receiving the information signal.
18. The wearable radar reflector of claim 1, wherein the retroreflector is configured to control the angular divergence of the retroreflected signal.
19. The wearable radar reflector of claim 1, wherein the retroreflector has a frequency-dependent response.
20. The wearable radar reflector of claim 1, wherein the retroreflector is a first retroreflector, and further comprising a second retroreflector attached to the garment.
21. The wearable radar reflector of claim 1, wherein the retroreflector is a corner cube.

22. The wearable radar reflector of claim 1, wherein the retroreflector is a composite corner cube.
23. The wearable radar reflector of claim 1, wherein the retroreflector is a Van Atta array.
24. The wearable radar reflector of claim 1, wherein the retroreflector is configured to reflect radiation having a frequency of about 70 to about 85 GHz.
25. A method of preventing collisions, comprising:
receiving a radar signal having a frequency of about 1 to about 300 GHz at a
pedestrian location from a radar source; and
retroreflecting the radar signal toward the radar source, wherein the retroreflection
indicates information to the radar source about a position of a pedestrian at
the pedestrian location.
26. The method of claim 25, wherein retroreflecting the radar signal toward the radar
source includes transmitting a response signal.
27. The method of claim 26, wherein transmitting a response signal includes encoding
the retroreflected radar signal.
28. The method of claim 27, wherein the retroreflected radar signal is encoded by a
spatial dependence of the retroreflection.
29. The method of claim 27, wherein retroreflecting the radar signal toward the radar
source includes vibrating a retroreflector to frequency encode information.
30. The method of claim 25, wherein retroreflecting the radar signal toward the radar
source includes retroreflecting the radar signal in response to a characteristic of
the radar signal.
31. The method of claim 25, further comprising storing movement data for the
pedestrian.

32. The method of claim 25, further comprising reporting movement data for the pedestrian.
33. The method of claim 25, wherein retroreflecting the radar signal toward the radar source includes controlling the angular divergence of the retroreflected radar signal.
34. A method of preventing collisions, comprising:
sending a radar signal having a frequency of about 1 to about 300 GHz from an operating vehicle;
receiving a retroreflected response radar signal from a pedestrian in response to the sent signal; and
taking action:
to prevent the operating vehicle from striking the pedestrian; or
to mitigate the effect of striking the pedestrian.
35. The method of claim 34, wherein taking action includes braking the operating vehicle.
36. The method of claim 34, wherein taking action includes changing the direction of the operating vehicle.
37. The method of claim 34, wherein taking action includes deploying a collision mitigation device.
38. The method of claim 37, wherein the collision mitigation device is selected from the group consisting of extendable bumpers, internal airbags, and external airbags.
39. The method of claim 34, wherein taking action includes interpreting data from the retroreflected response radar signal to select an action.
40. The method of claim 34, wherein the pedestrian is a first pedestrian and the retroreflected response radar signal is a first retroreflected response radar signal, further comprising receiving a second retroreflected response radar signal from a second pedestrian in response to the sent radar signal.

41. The method of claim 40, wherein taking action includes taking action to prevent the operating vehicle from striking either the first pedestrian or the second pedestrian.
42. The method of claim 40, wherein taking action includes prioritizing whether the operating vehicle should strike the first pedestrian or the second pedestrian.
43. The method of claim 34, wherein the retroreflected response radar signal is a first retroreflected response radar signal, further comprising receiving a second retroreflected response radar signal from a detected vehicle in response to the sent radar signal.
44. The method of claim 43, wherein taking action includes prioritizing whether the operating vehicle should strike the pedestrian or the detected vehicle.
45. A radar identification device, comprising:
a memory configured to store demographic information for a user; and
a radar retroreflector, configured to be worn or carried by the user and further configured to modulate a retroreflected radar signal in the frequency range of about 1 to about 300 GHz with at least a subset of the stored demographic information.
46. The device of claim 45, wherein the memory is configured to update the stored demographic information.
47. The device of claim 45, wherein the memory is configured to be worn or carried by the user.
48. The device of claim 45, wherein the radar retroreflector is configured to select what demographic information to include in the modulated retroreflected radar signal.
49. The device of claim 45, wherein the radar retroreflector is a first radar retroreflector, the device further comprising a second radar retroreflector configured to be worn or carried by the user.

50. The device of claim 49, wherein the first radar retroreflector and the second radar retroreflector are configured to produce the same modulated retroreflected radar signal.
51. The device of claim 49, wherein the first radar retroreflector and the second radar retroreflector are configured to produce differing modulated retroreflected radar signals.
52. The device of claim 45, wherein the radar retroreflector is configured to modulate the retroreflected signal ultrasonically.
53. The device of claim 45, wherein the demographic information includes that the user is a pet.
54. The device of claim 53, wherein the demographic information further includes the leash status of the pet.
55. A wearable radar identification system, comprising:
an identification structure having a defined radar identification signature for radar in the frequency range of about 1 to about 300 GHz, the signature being associated with demographic information for an associated user; and
a garment incorporating the identification structure, configured to be worn by the associated user.
56. The system of claim 55, wherein the identification structure includes an array of retroreflectors.
57. The system of claim 56, wherein the retroreflectors of the array have positions that encode the demographic information.
58. The system of claim 55, wherein the identification structure includes a modulated retroreflector.
59. The system of claim 55, wherein the identification structure includes a radar beacon.

- 60. The system of claim 59, wherein the radar beacon is radar triggered.
- 61. The system of claim 55, wherein the identification structure includes a radar reflector.
- 62. The system of claim 55, wherein the identification structure has a defined radar identification signature for radar in the frequency range of about 50 to about 100 GHz.
- 63. The system of claim 55, wherein the identification structure has a defined radar identification signature for radar in the frequency range of about 70 to about 85 GHz.
- 64. A method of preventing collisions, comprising:
 - receiving a radar signal having a frequency of about 1 to about 300 GHz at a pedestrian location from a radar source; and
 - transmitting a response signal toward the radar source, wherein the response signal includes demographic information about the pedestrian, and wherein the response signal is sent without action by the pedestrian.
- 65. The method of claim 64, wherein transmitting the response signal includes transmitting the response signal in response to receiving the radar signal.
- 66. The method of claim 64, wherein transmitting the response signal includes retroreflecting the radar signal back toward the radar source, and wherein the retroreflected signal encodes the demographic information about the pedestrian.
- 67. The method of claim 66, wherein retroreflecting the radar signal includes retroreflecting the radar signal with an array of retroreflectors, and wherein the positions of the retroreflectors of the array encode the demographic information about the pedestrian.
- 68. The method of claim 66, wherein the retroreflected signal encodes the demographic information by modulating the retroreflected signal.

69. The method of claim 64, wherein transmitting the response signal includes using a radar beacon.
70. The method of claim 64, wherein transmitting the response signal includes reflecting the radar signal with a radar reflector.
71. The method of claim 64, wherein the pedestrian is a child, and the method includes transmitting a response signal only if the child is unaccompanied by an adult.
72. The method of claim 64, wherein the pedestrian is a pet, and the method includes transmitting a response signal only if the pet is off-leash.
73. The method of claim 64, wherein the method includes transmitting a response signal only if the pedestrian is within a predetermined distance from a roadway.
74. The method of claim 73, wherein the predetermined distance is determined by a user.
75. The method of claim 64, wherein the method includes transmitting a response signal in response to a position of the pedestrian.
76. A method of preventing collisions, comprising:
sending a radar signal from an operating vehicle;
receiving a response signal from a pedestrian in response to the sent signal, the response signal including demographic information about the pedestrian;
and
taking action to prevent the operating vehicle from striking the pedestrian or to mitigate the effect of striking the pedestrian.
77. The method of claim 76, wherein taking action includes selecting an action in response to the demographic information.
78. A pedestrian warning device, comprising:

a radar detector configured to be worn or carried by a pedestrian and to detect radar signals emanating from a vehicle; and
an alarm configured to warn the pedestrian of the vehicle.

- 79. The device of claim 78, wherein the alarm is audible.
- 80. The device of claim 79, wherein the alarm includes a prerecorded voice.
- 81. The device of claim 79, wherein the alarm includes a synthesized voice.
- 82. The device of claim 79, wherein the alarm indicates a location of the vehicle.
- 83. The device of claim 78, wherein the alarm is visual.
- 84. The device of claim 78, wherein the alarm is haptic.
- 85. The device of claim 78, wherein the alarm includes a command for the pedestrian.
- 86. The device of claim 85, wherein the command is selected from the group consisting of a direction to freeze, a direction to slow down, a direction to speed up, a direction to move in a particular direction, and a direction to brake.
- 87. The device of claim 78, wherein the alarm includes information about the vehicle.
- 88. The device of claim 87, wherein the information includes at least one item from the group consisting of direction, proximity, range, time-to-impact, color, make, and model.
- 89. The device of claim 78, further comprising a decision unit configured to determine whether to sound the alarm.
- 90. The device of claim 89, wherein the decision unit is configured to determine whether to sound the alarm based at least in part on information selected from the group consisting of the pedestrian's position, the pedestrian's orientation, the pedestrian's movement direction, the pedestrian's speed, the pedestrian's companions, the pedestrian's movement history, the vehicle's range, the vehicle's

direction, the vehicle's speed, the vehicle's time to impact, and the position of a second vehicle.

91. The device of claim 89, wherein the decision unit is configured to customize the alarm based at least in part on information selected from the group consisting of the pedestrian's position, the pedestrian's orientation, the pedestrian's movement direction, the pedestrian's speed, the pedestrian's companions, the pedestrian's movement history, the vehicle's range, the vehicle's direction, the vehicle's speed, the vehicle's time to impact, and the position of a second vehicle.
92. The device of claim 78, further comprising transmission means configured to communicate to the vehicle.
93. The device of claim 92, wherein the transmission means include a radar transmitter.
94. The device of claim 92, wherein the transmission means include a lidar transmitter.
95. The device of claim 92, wherein the transmission means include a reflector.
96. The device of claim 92, wherein the transmission means include a retroreflector.
97. The device of claim 92, wherein the transmission means are configured to communicate to the vehicle information selected from the group consisting of reporting of detection of vehicle, issued alert, the pedestrian's position, the pedestrian's speed, and pedestrian's response to alert.
98. The device of claim 78, further comprising a recording unit configured to record at least one member of the group consisting of the signal emanating from the vehicle, the time of the signal, the location of the vehicle, the location of the pedestrian, the speed of the vehicle, the direction of the vehicle, the time-to-impact, the speed of the pedestrian, the position of the pedestrian, any alarms issued, and any reaction of the pedestrian to an issued alarm.

99. The device of claim 78, further comprising control means configured to issue a control directive to a pedestrian vehicle under control of the pedestrian.
100. The device of claim 99, wherein the pedestrian vehicle is selected from the group consisting of a bicycle, an electric-assisted bicycle, a skateboard, a motorized skateboard, a scooter, a motorized skateboard, a motorized scooter, a personal transporter, a wheelchair, and a powered wheelchair.
101. The device of claim 99, wherein the control directive is selected from the group consisting of a command to brake, a command to stop, a command to change direction, a command to change speed, and a command to activate a driver alert.
102. The device of claim 78, wherein the device is a cellular telephone.
103. The device of claim 78, wherein the device is configured to determine a characteristic of the detected radar signal.
104. The device of claim 103, wherein the determined characteristic is selected from the list consisting of direction, frequency, Doppler shifts, amplitude, and waveform.
105. The device of claim 103, wherein the determined characteristic includes informational modulation of the radar signal.
106. The device of claim 78, further comprising an accelerometer.
107. The device of claim 106, further comprising a control system configured to use data from the accelerometer to determine a response of the pedestrian to the warning.
108. The device of claim 78, further comprising a GPS receiver.
109. The device of claim 78, further comprising a digital memory configured to store digital mapping data.
110. A pedestrian warning device, comprising:

- a lidar detector configured to be worn or carried by a pedestrian and to detect lidar signals emanating from a vehicle; and
an alarm configured to warn the pedestrian of the vehicle.
111. A method of warning a pedestrian of a vehicle, comprising:
receiving a radar signal from the vehicle at a radar detector configured to be worn or carried by the pedestrian; and
alerting the pedestrian with an alarm.
112. The method of claim 111, wherein alerting the pedestrian includes alerting the pedestrian with a sound.
113. The method of claim 112, wherein the sound includes a prerecorded voice.
114. The method of claim 112, wherein the sound includes a synthesized voice.
115. The method of claim 112, wherein the sound indicates the position of the vehicle.
116. The method of claim 111, further comprising transmitting a response signal back to the vehicle.
117. The method of claim 111, further comprising transmitting a control directive to a pedestrian vehicle under control of the pedestrian.
118. A method of warning a pedestrian of a vehicle, comprising:
receiving a lidar signal from the vehicle at a lidar detector configured to be worn or carried by the pedestrian; and
alerting the pedestrian with an alarm.
119. A pedestrian warning device, comprising:
a vehicle detector configured to be worn or carried by a pedestrian and to detect signals emanating from a vehicle; and
an alarm configured to warn the pedestrian of the vehicle.

120. The device of claim 119, wherein the vehicle detector comprises a wide-angle camera.
121. The device of claim 119, further comprising a transmitter configured to transmit information about the pedestrian to the vehicle.
122. A pedestrian warning system, comprising:
a beacon radar transmitter configured to transmit a radar signal including vehicle information, wherein the transmitted signal may be received by a pedestrian to communicate vehicle information to the pedestrian.
123. The system of claim 122, wherein the vehicle information is selected from the group consisting of speed, direction, position, maximum speed, braking capabilities, turning capabilities, make, model, color, and driver identifying information.
124. A pedestrian warning device, comprising:
a computing device configured to be worn or carried by a pedestrian and to monitor an attention level of the pedestrian; and
an alarm configured to warn the pedestrian of a vehicle detected by the computing device.
125. The pedestrian warning device of claim 124, wherein the pedestrian warning device includes a camera configured to detect the vehicle.
126. The pedestrian warning device of claim 124, wherein the pedestrian warning device includes a microphone configured to detect the vehicle
127. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian only if a predicted collision probability is determined to be above a threshold.
128. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian only if the attention level is determined to be below a threshold.

129. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to the attention level of the pedestrian.
130. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in a mode selected in response to the attention level of the pedestrian.
131. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in a mode selected in response to an activity type of the pedestrian.
132. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to an attention history of the pedestrian.
133. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to an eye position of the pedestrian.
134. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to an eye position history of the pedestrian.
135. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to a head orientation of the pedestrian.
136. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to a head orientation history of the pedestrian.
137. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to a position of the pedestrian.
138. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to a motion of the pedestrian.
139. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to a position of the computing device.

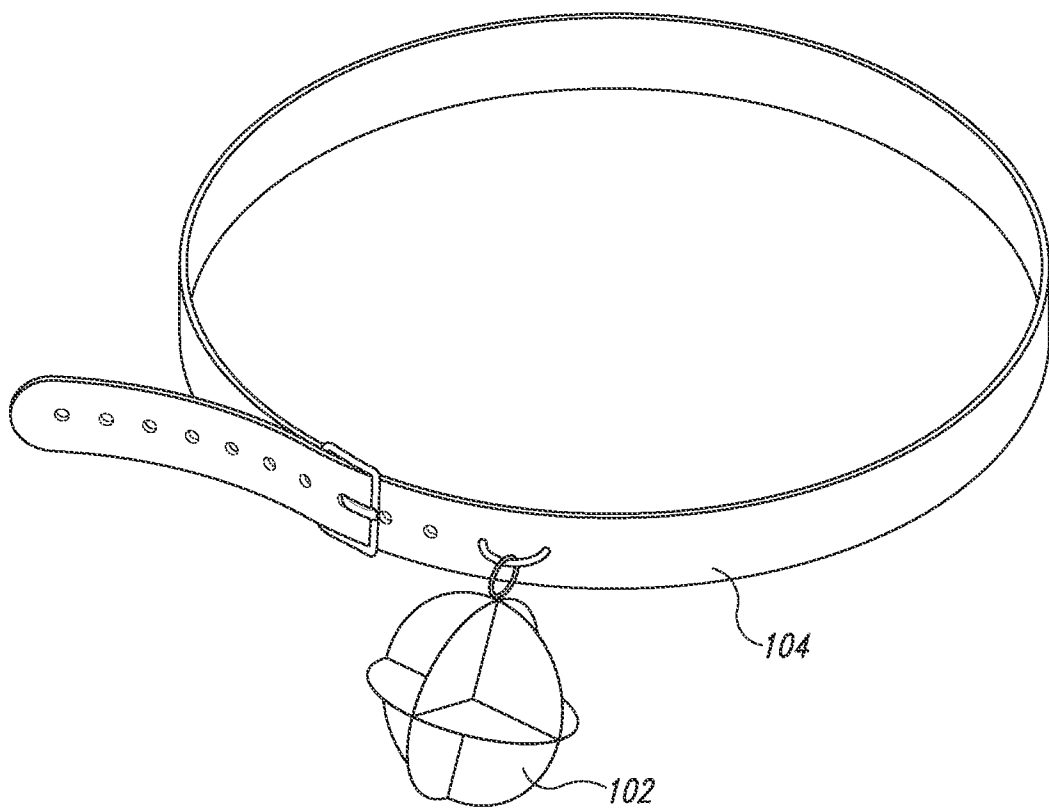
140. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to an orientation of the computing device.
141. The pedestrian warning device of claim 124, wherein the alarm is configured to warn the pedestrian in response to an alarm response history of the pedestrian.
142. The pedestrian warning device of claim 124, wherein the computing device is a mobile telephone.
143. The pedestrian warning device of claim 124, wherein the computing device is a wearable device.
144. The pedestrian warning device of claim 124, further comprising a GPS configured to identify a location of the pedestrian.
145. The pedestrian warning device of claim 144, wherein the GPS is configured to identify whether the pedestrian is crossing a street at an intersection.
146. The pedestrian warning device of claim 144, wherein the pedestrian warning device is configured to monitor the gaze of the pedestrian, and the alarm is configured to warn the pedestrian in response to an attempt to cross a street without looking in a direction of oncoming traffic.
147. The pedestrian warning device of claim 144, wherein the pedestrian warning device is configured to monitor the head position of the pedestrian, and the alarm is configured to warn the pedestrian in response to an attempt to cross a street without looking in a direction of oncoming traffic.
148. The pedestrian warning device of claim 124, wherein the pedestrian warning device is configured to monitor the gaze of the pedestrian, and the alarm is configured to warn the pedestrian in response to an attempt to cross a street without looking in a direction of oncoming traffic.
149. The pedestrian warning device of claim 124, wherein the pedestrian warning device is configured to monitor the head position of the pedestrian, and the alarm

- is configured to warn the pedestrian in response to an attempt to cross a street without looking in a direction of oncoming traffic.
150. The pedestrian warning device of claim 124, further comprising a sensor configured to monitor a traffic signal.
151. The pedestrian warning device of claim 150, wherein the alarm is configured to warn the pedestrian in response to an attempt to cross a street in contravention of the traffic signal.
152. The pedestrian warning device of claim 124, further comprising a memory.
153. The pedestrian warning device of claim 152, wherein the memory is configured to store a record of the pedestrian's actions.
154. The pedestrian warning device of claim 152, wherein the memory is configured to store a record of vehicle detections.
155. The pedestrian warning device of claim 152, wherein the memory is configured to store a record of alarms issued.
156. A method of warning a pedestrian of a vehicle, comprising:
monitoring an attention level of the pedestrian by monitoring an electronic device carried or worn by the pedestrian;
detecting a vehicle; and
in response to the detected vehicle and the monitored attention level, alerting the pedestrian to the presence of the vehicle.
157. The method of claim 156, wherein monitoring the attention level includes monitoring a device activity of the pedestrian.
158. The method of claim 157, wherein alerting the pedestrian includes selecting an alert mode in response to the device activity of the pedestrian.

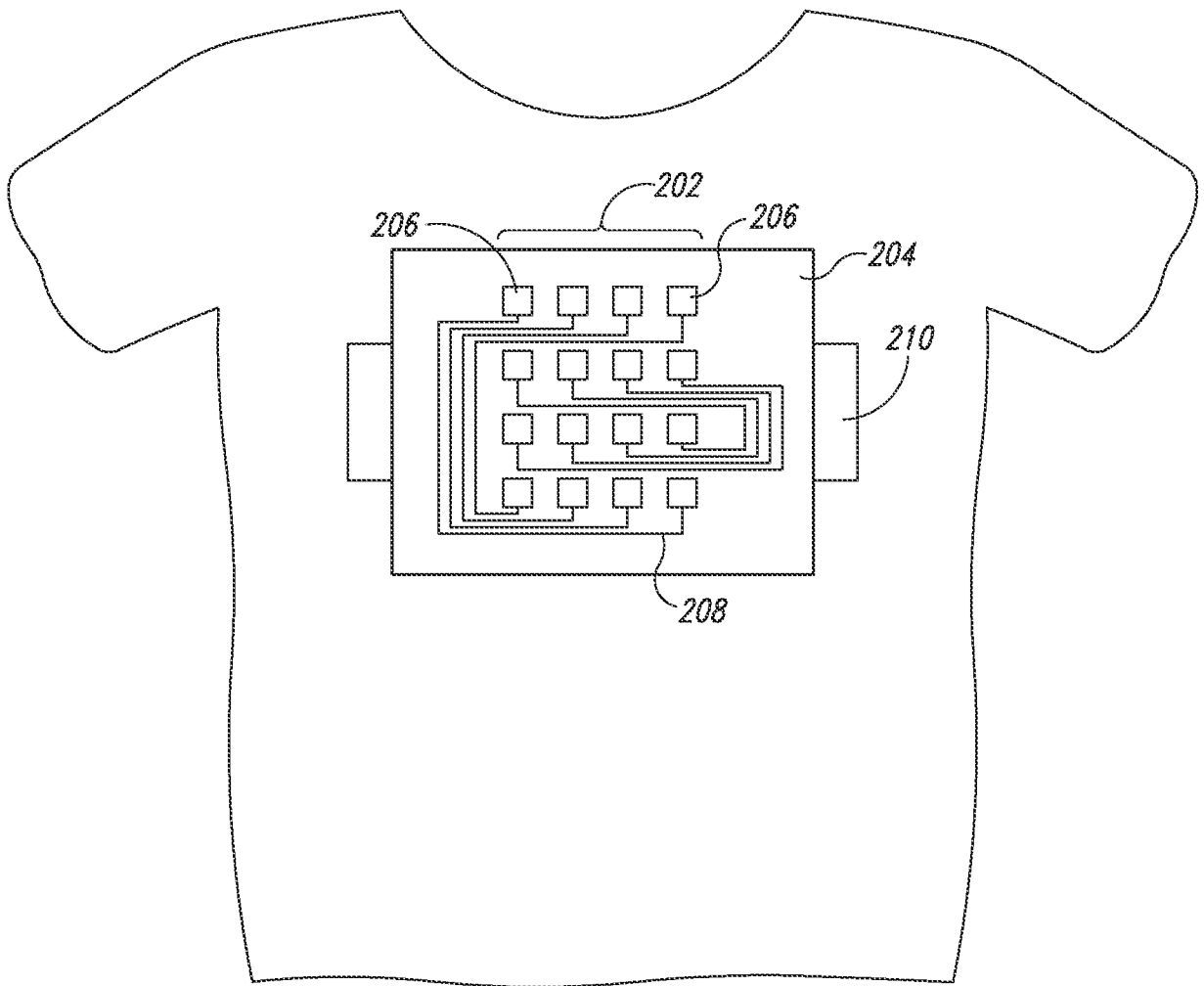
159. The method of claim 158, wherein the device activity is selected from the group consisting of typing, talking, taking a picture, taking a video, having a video conference, playing a timed game, playing an untimed game, reading, watching a display, and using a display-based application.
160. The method of claim 156, further comprising storing a record of the pedestrian's actions in a memory.
161. The method of claim 156, further comprising storing a record of vehicle detections in a memory.
162. The method of claim 156, further comprising storing a record of pedestrian alerts in a memory.
163. A system for monitoring the behavior of a pedestrian, comprising:
a computing device configured:
 to be worn or carried by a pedestrian;
 to monitor an attention level of the pedestrian; and
 to detect a vehicle; and
a memory configured to store information about the actions of the pedestrian.
164. The system of claim 163, further comprising a transmitter configured to transmit information about the actions of the pedestrian to a remote location.
165. The system of claim 163, further comprising a display configured to display information stored in the memory.
166. The system of claim 163, wherein the device is configured to store a record of pedestrian activity.
167. The system of claim 163, wherein the memory is configured to store a gaze direction of the pedestrian.
168. The system of claim 163, wherein the memory is configured to store a head position of the pedestrian.

169. The system of claim 163, wherein the memory is configured to store an orientation of the device.
170. The system of claim 163, wherein the memory is configured to store a record of vehicle detections.
171. A method for monitoring the behavior of a pedestrian, comprising:
monitoring an attention level of the pedestrian;
monitoring a position of the pedestrian;
monitoring a motion of the pedestrian; and
alerting the pedestrian if the pedestrian is determined to be in danger from a vehicle in response to the monitored attention level, the monitored position, and the monitored motion of the pedestrian.
172. The method of claim 171, wherein monitoring the position of the pedestrian includes determining the proximity of the pedestrian to a street.
173. The method of claim 171, wherein monitoring a motion of the pedestrian includes determining that the pedestrian is moving toward a street.
174. The method of claim 171, wherein alerting the pedestrian includes warning the pedestrian in response to an alarm response history of the pedestrian.

1/7
FIG. 1



2/7
FIG. 2



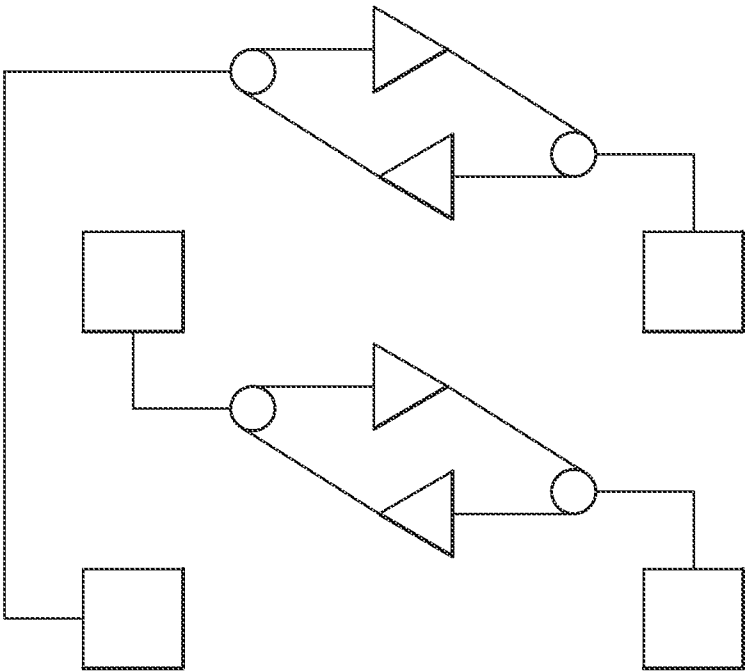


FIG. 3

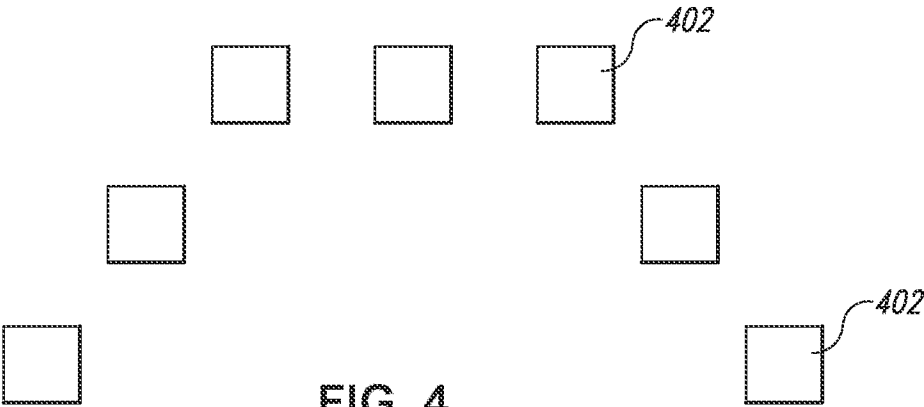
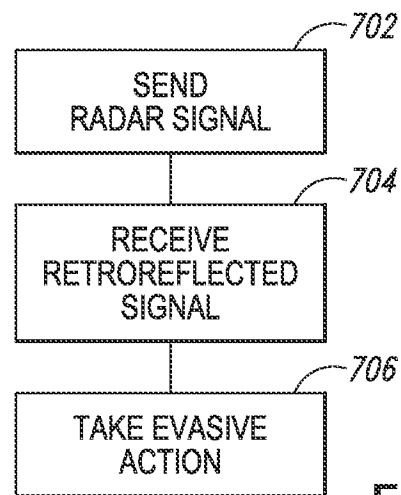
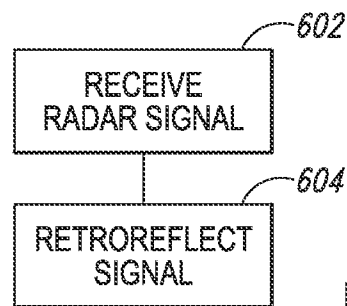
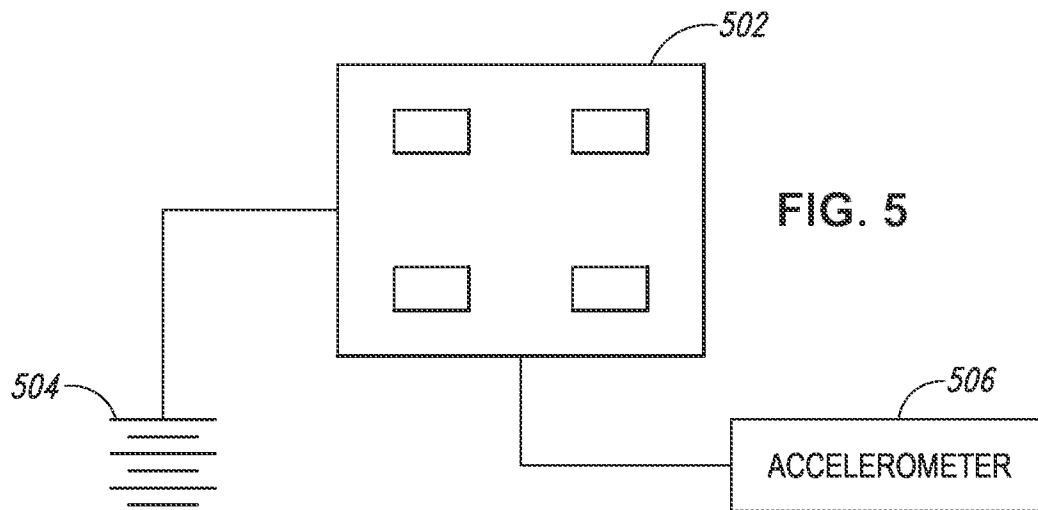
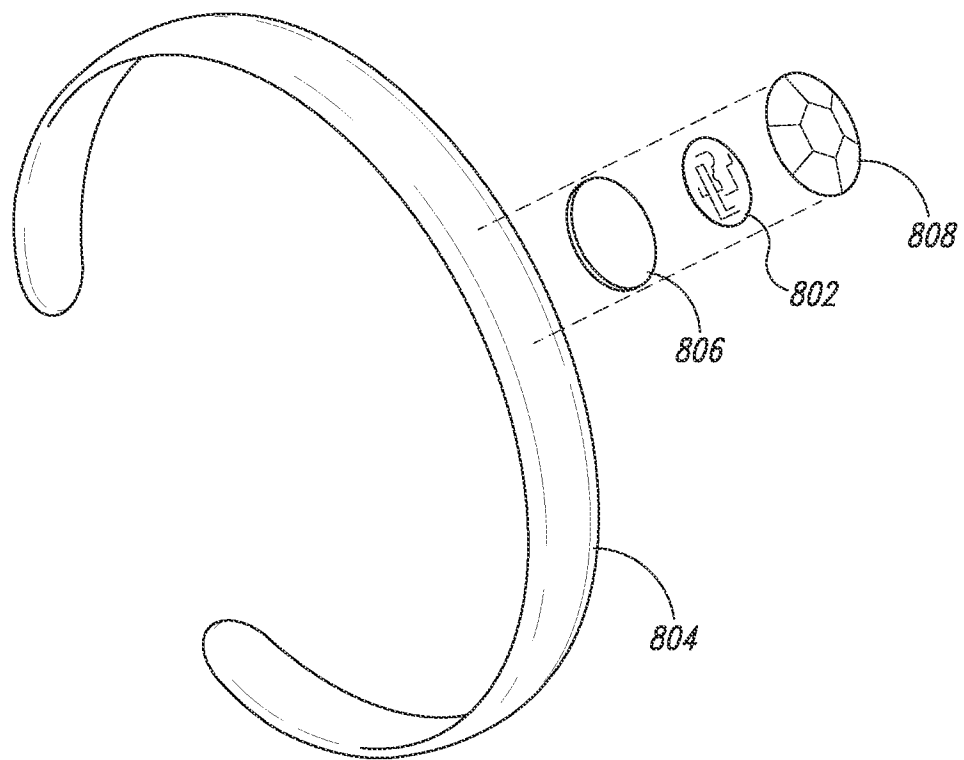


FIG. 4

4/7



5/7
FIG. 8



6/7

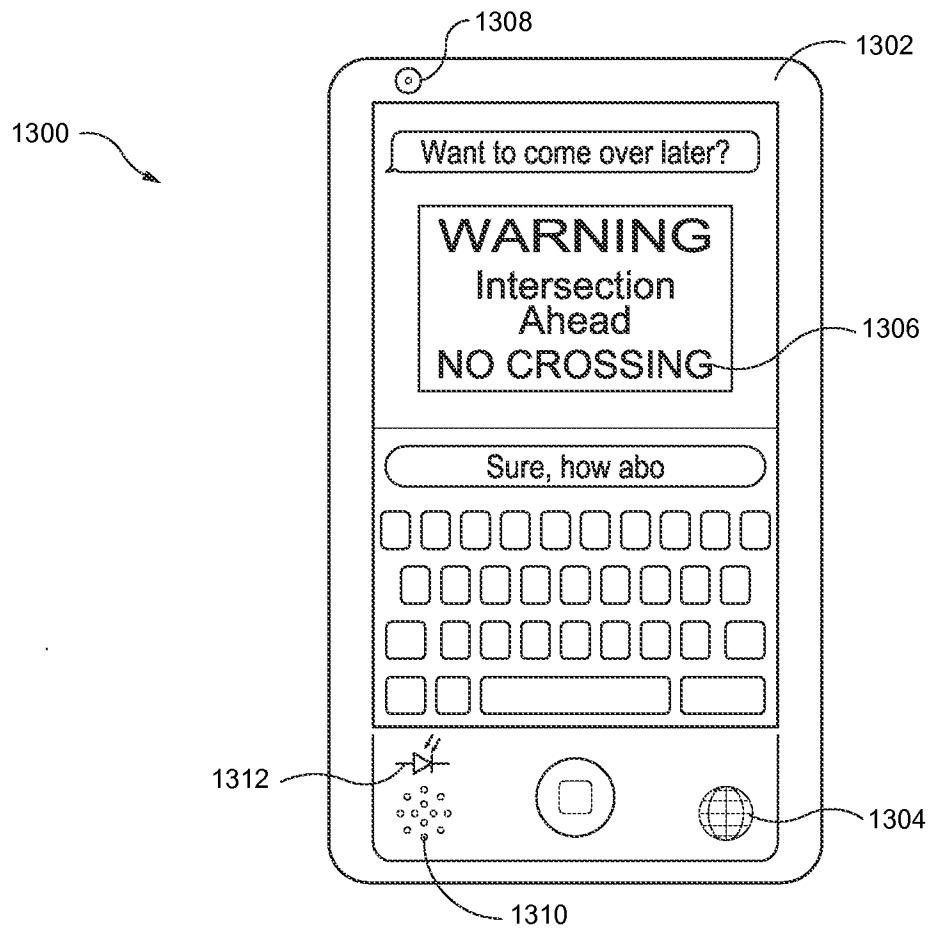


FIG. 9

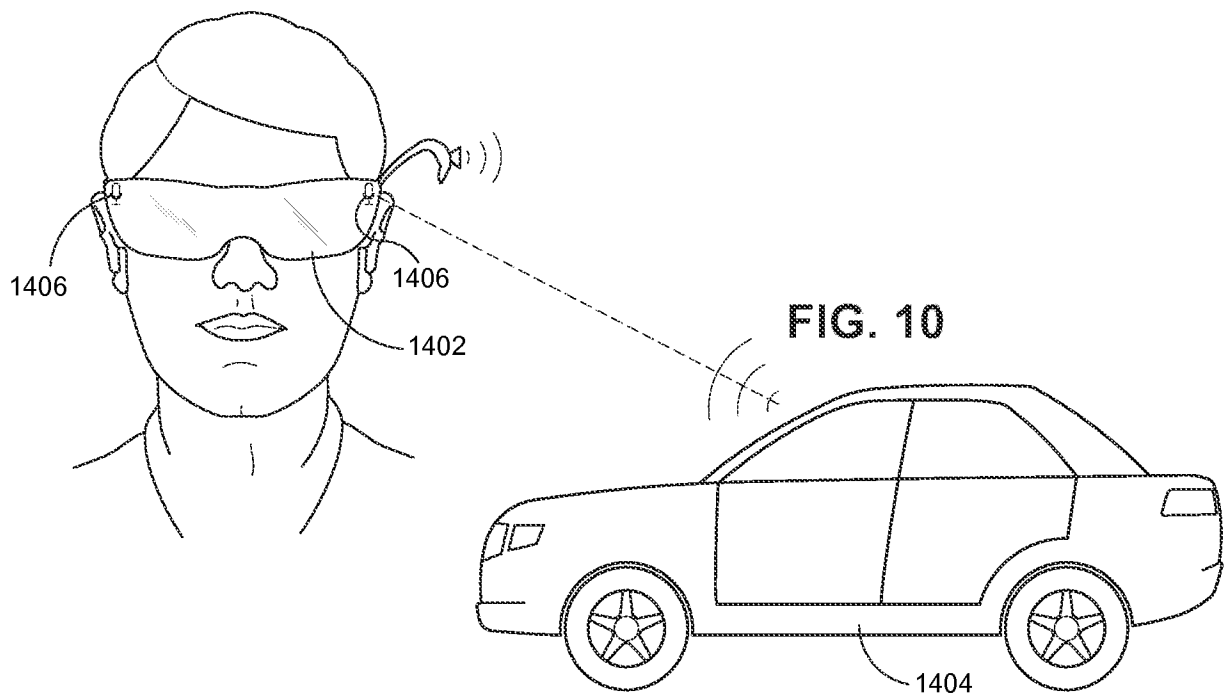
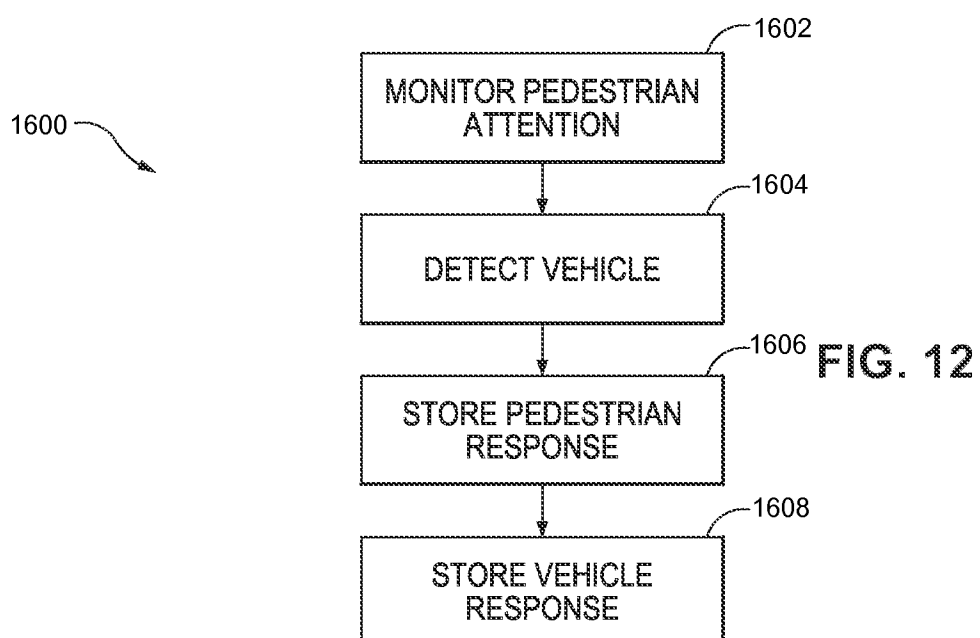
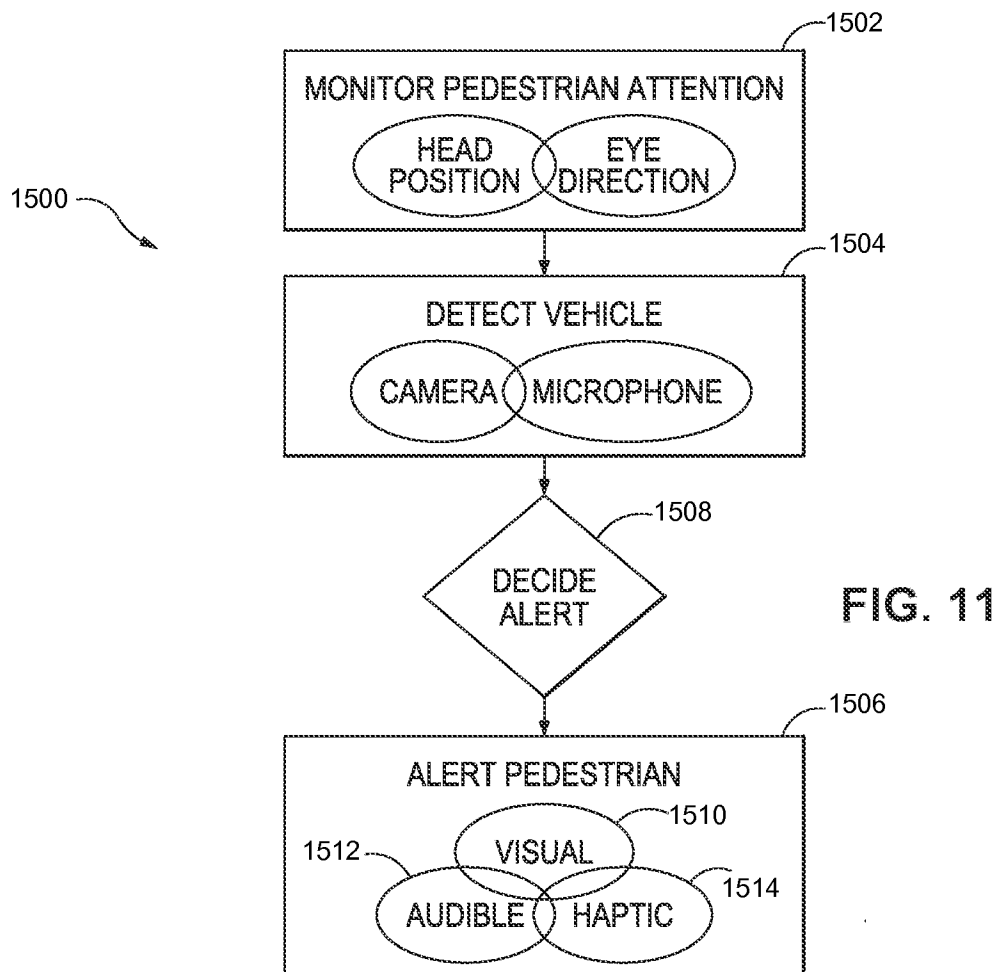


FIG. 10

7/7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/047543**A. CLASSIFICATION OF SUBJECT MATTER****G01S 13/93(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01S 13/93; G08G 1/0967; G06K 9/32; B60Q 1/00; G08G 1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: retroreflect, vehicle, pedestrian, warm

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0094712 A1 (SAID) 18 April 2013 See abstract, paragraphs [0018]-[0022], claim 1 and figures 1-3.	1-77
A		78-174
X	US 2011-0090093 A1 (GRIMM et al.) 21 April 2011 See abstract, paragraphs [0011]-[0029], claims 1, 8-9 and figure 1.	78-123
Y		1-33, 45-75, 124-174
Y	US 2008-0042894 A1 (KIKUCHI) 21 February 2008 See abstract, paragraphs [0064]-[0066], claim 1 and figure 1.	34-44, 76-77 , 124-174
A	US 2013-0015963 A1 (STEGMAIER et al.) 17 January 2013 See paragraphs [0023]-[0085], claims 1-5 and figures 1-6.	1-174
A	US 2013-0141576 A1 (LORD et al.) 06 June 2013 See abstract, claims 1-10 and figures 1A-2.	1-174



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

12 November 2014 (12.11.2014)

Date of mailing of the international search report

12 November 2014 (12.11.2014)

Name and mailing address of the ISA/KR

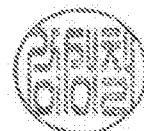
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/047543

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